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Response of rock-scour protection to earthquake-induced liquefaction for offshore wind applications

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Presentation Roadmap

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   - Motivation
2. Centrifuge testing
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   - Model design
   - Test parameters
3. Results
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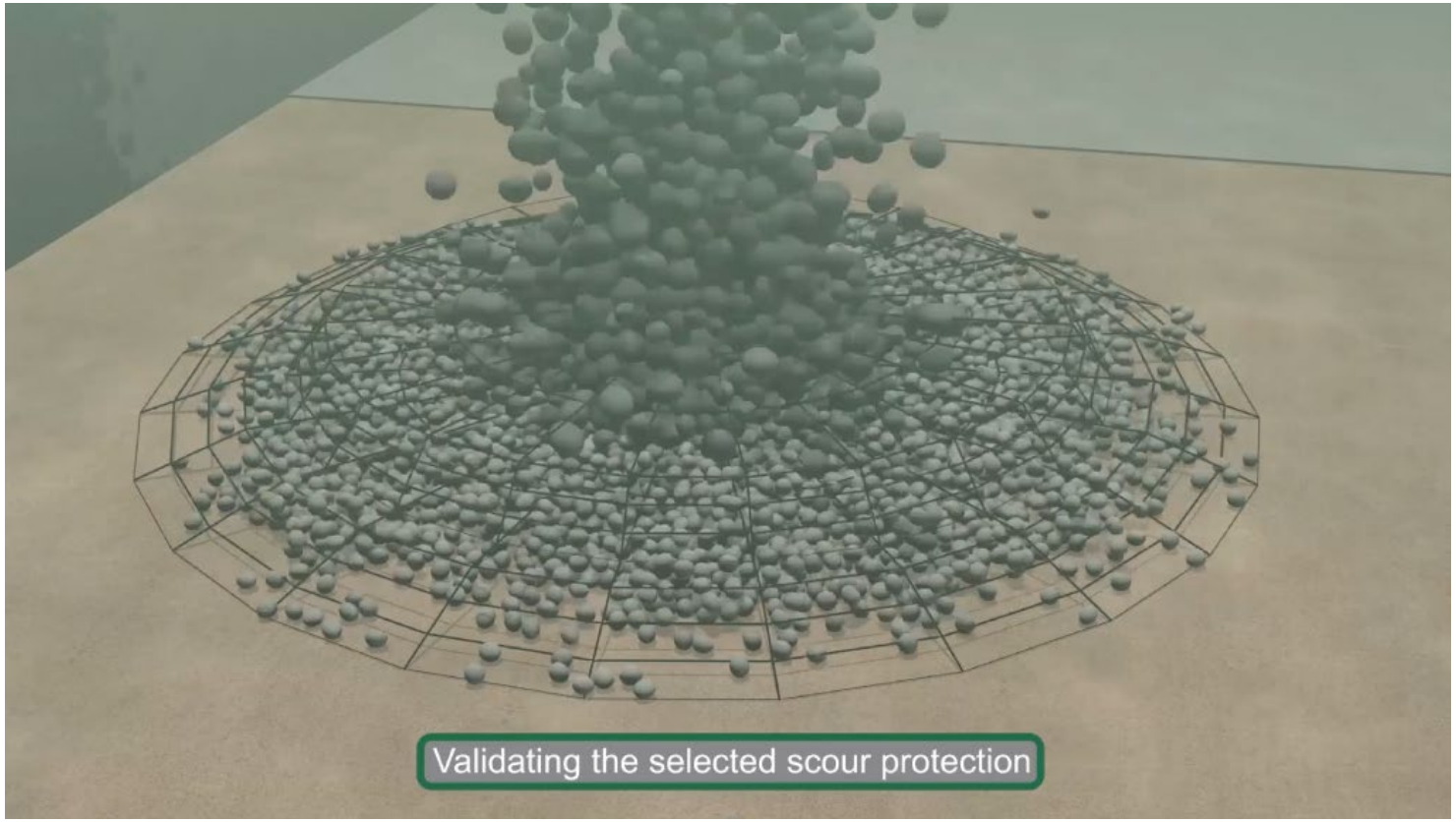
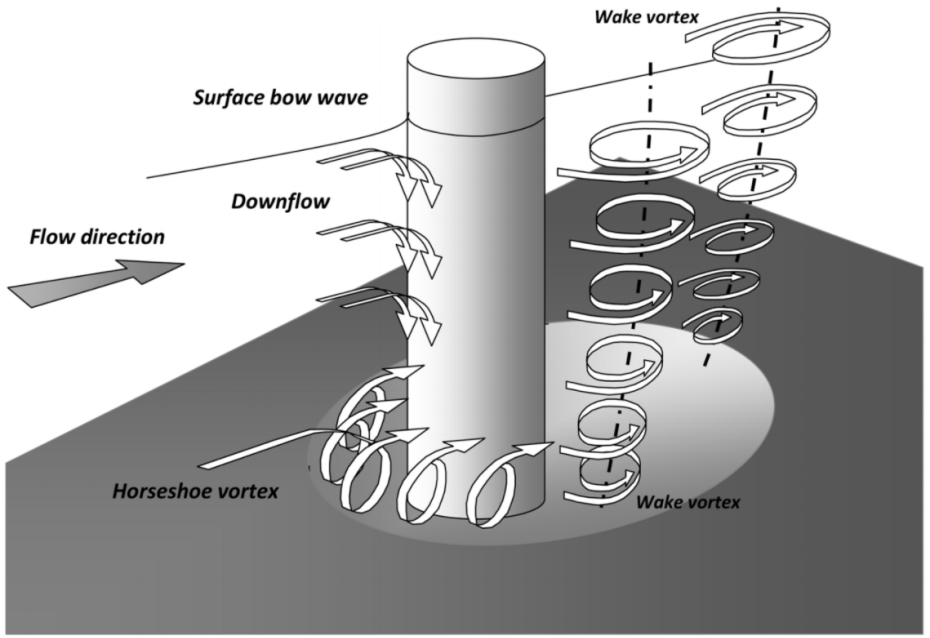
   - Excess pore pressure comparison
   - Rock settlement comparison
4. Conclusions and future work

Introduction: Scour



Motivation

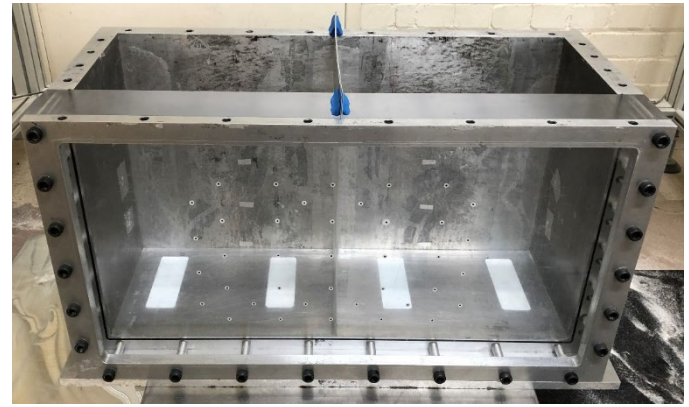
- The current approach:
  - Install scour protection
  - Deep embedment depth
  - “Monitor and react”
- Limited information on seismic behaviour.
- Timescale uncertainty.
- Limited geotechnical information.
- Lack of large scale experiments.

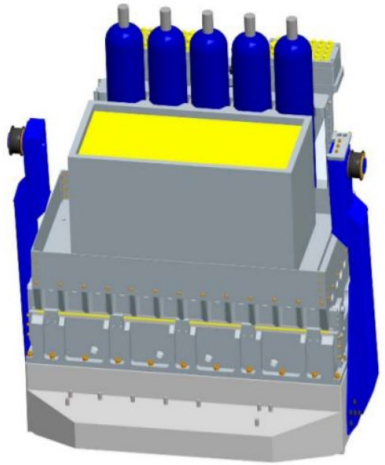


Harris *et al.* (2019) adapted from Melville and Coleman (2000)

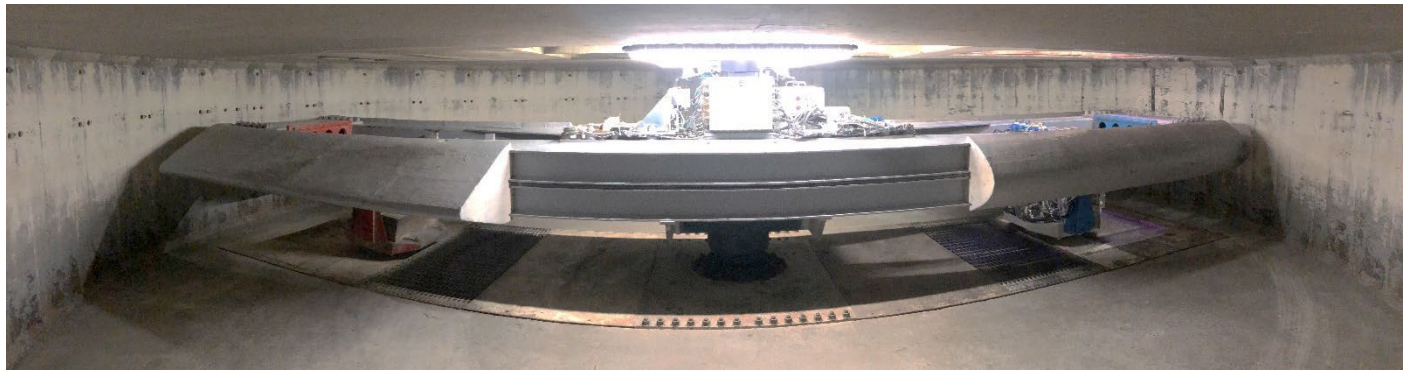
Turner Beam Centrifuge

- Proposed in 1969, 10m diameter
- “Scale” testing of non-linear behavior of soils
- 150*g*-ton capacity
- Model box: 730x397x250mm
- Earthquake simulation via servo-hydraulic shaker

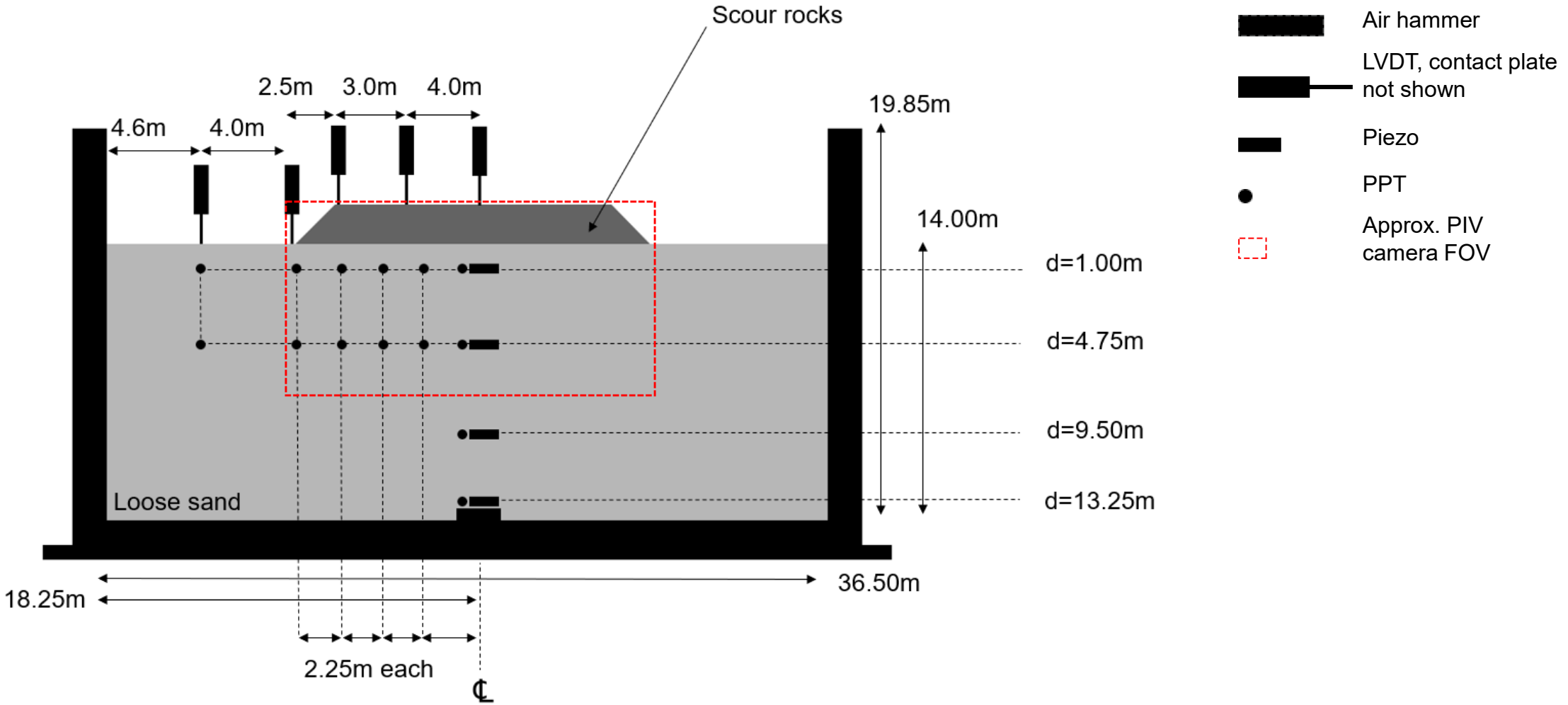




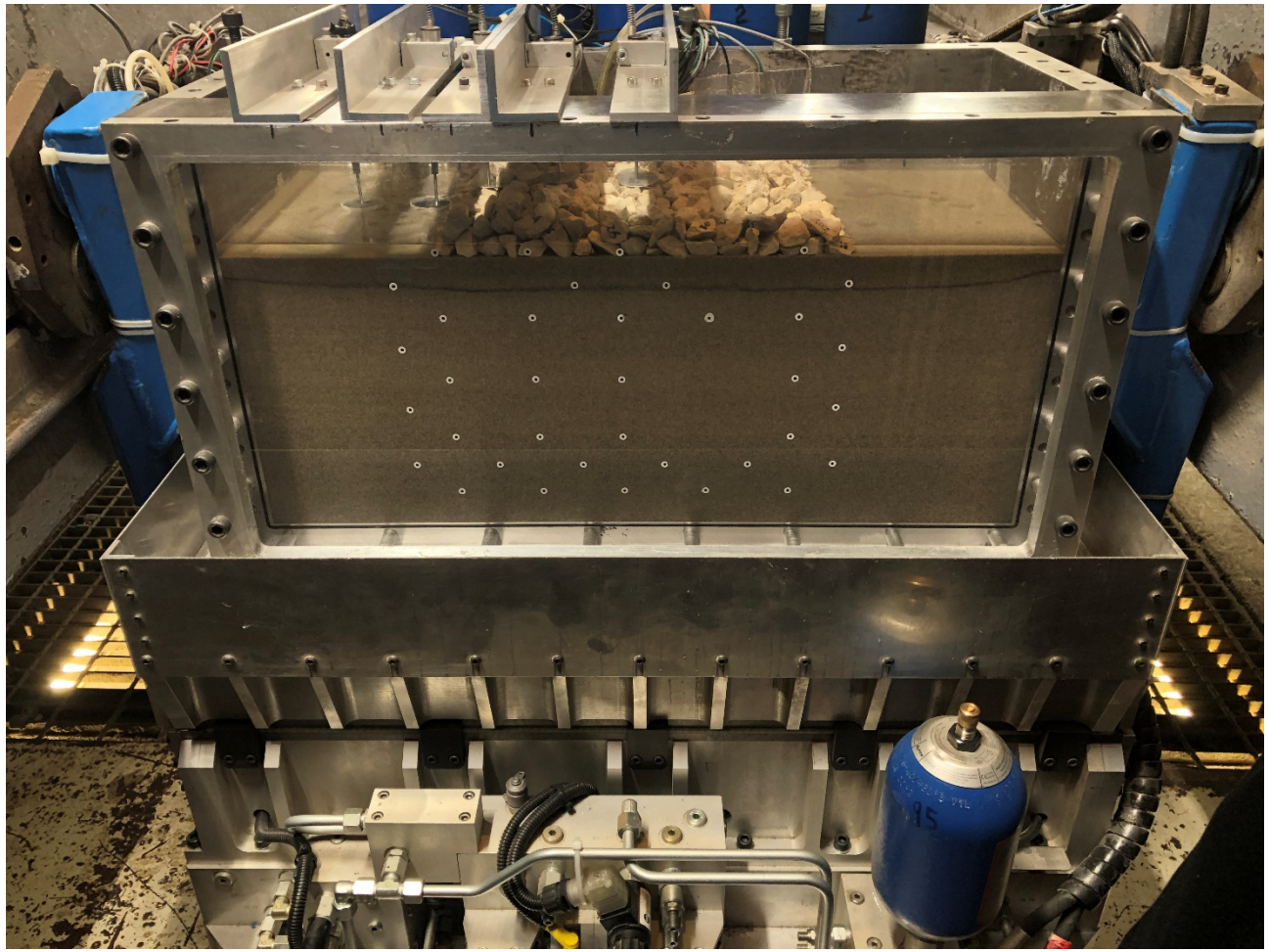
Madabhushi *et al.* (2012)

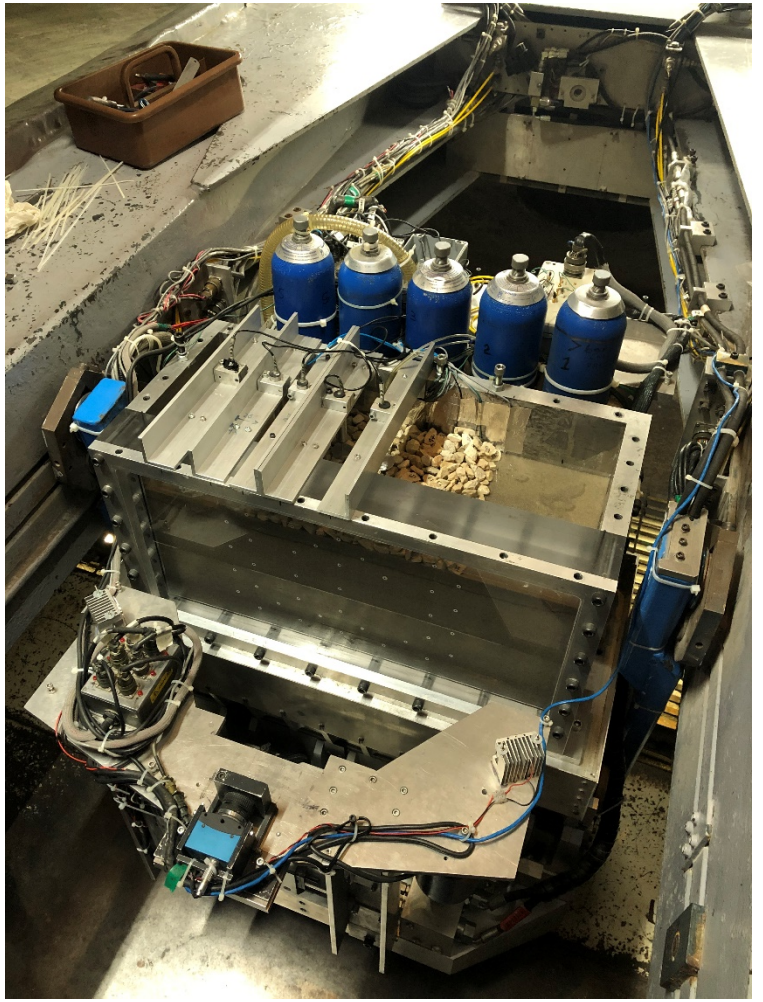


Centrifuge testing: test schematic



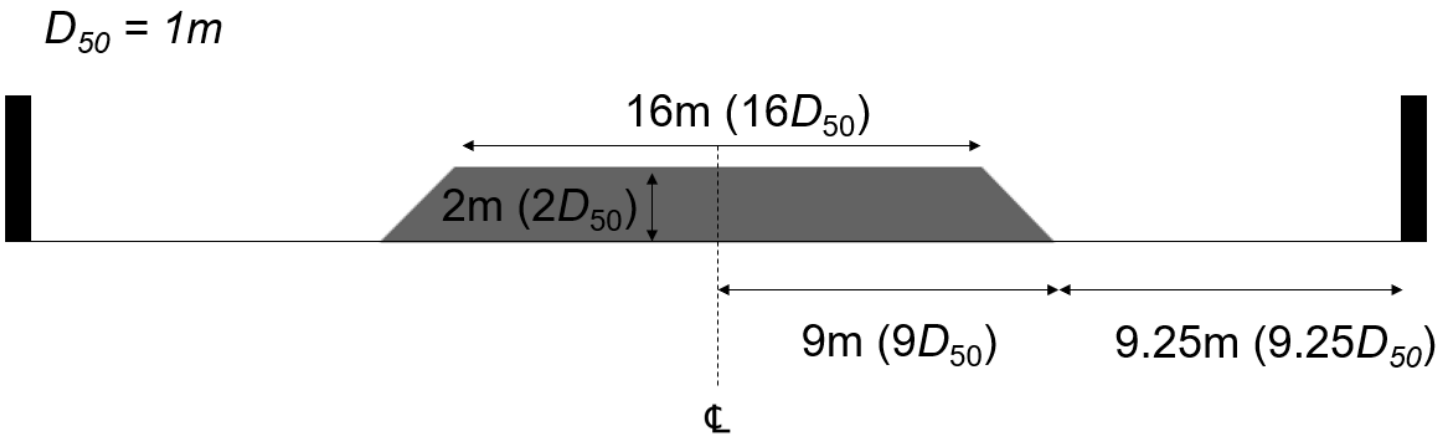
Centrifuge testing

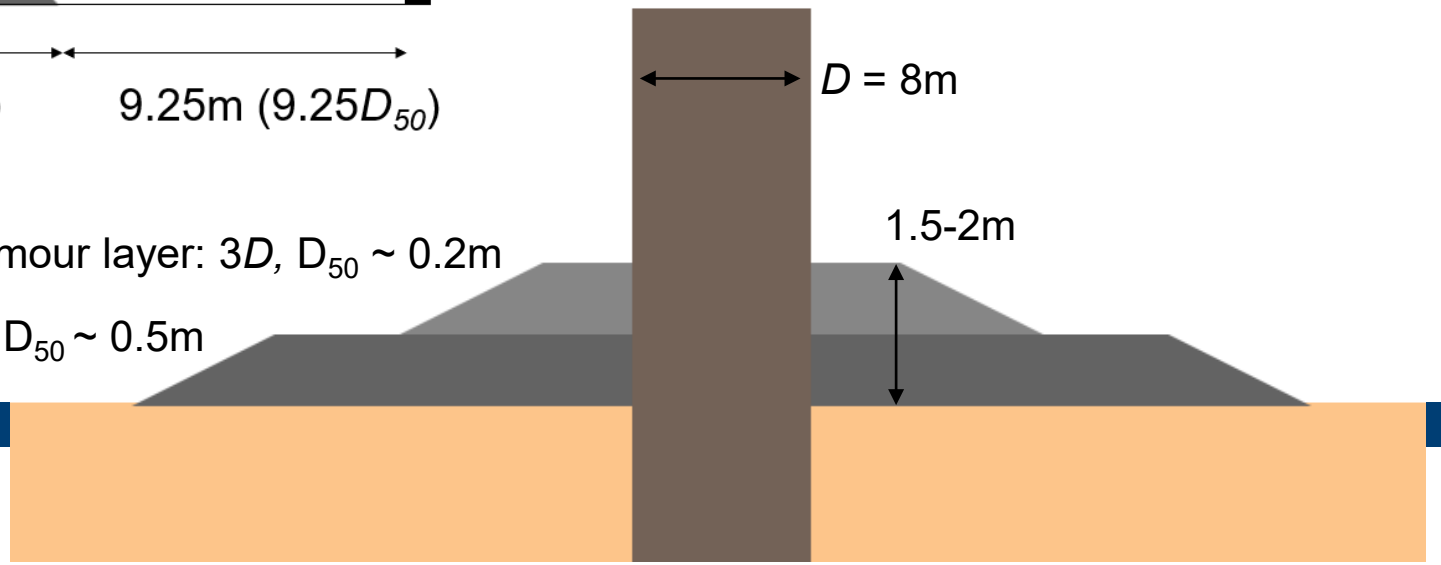




Centrifuge testing: model design and test parameters

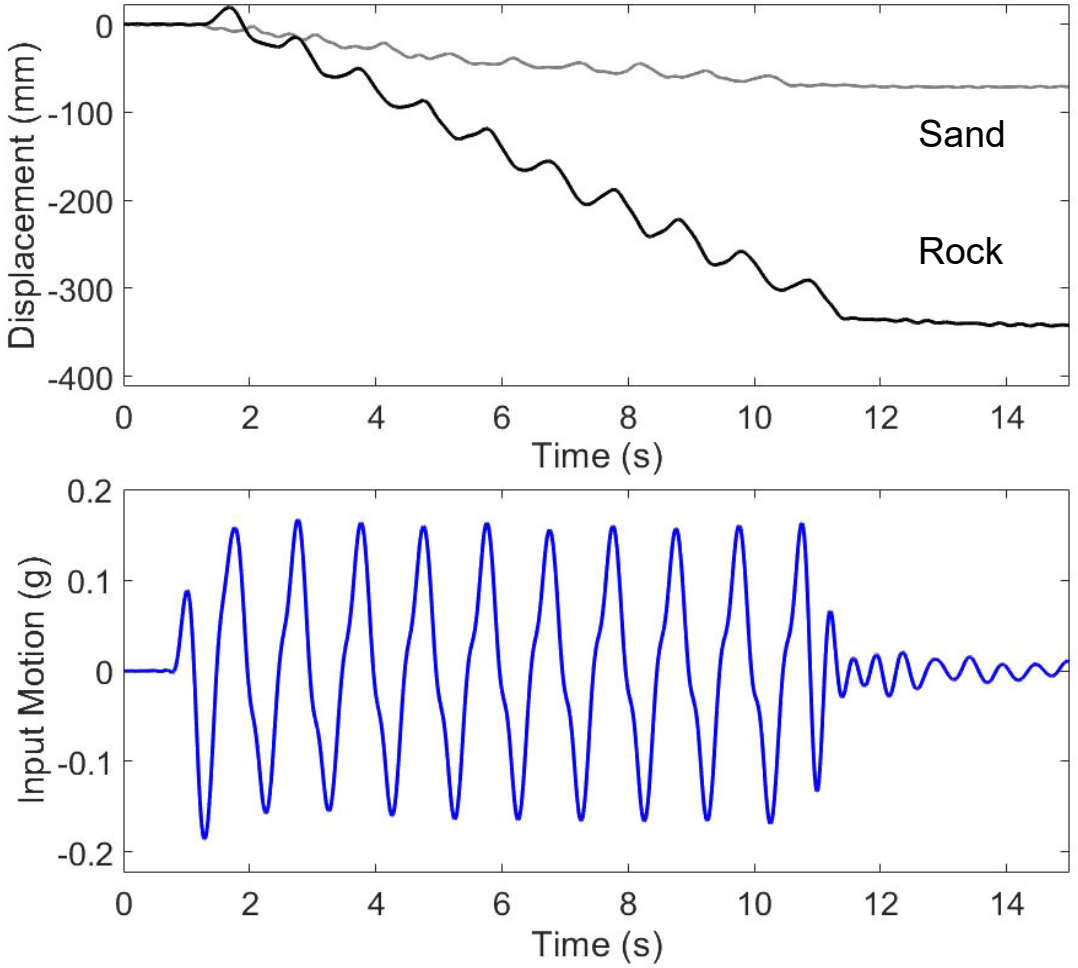
- 50*g* test, loose Hostun HN31 sand (45%, d_{50} = 0.44mm)
- Rock Gs = 2.62 (limestone), D_{50} = 1m and 0.5m
- Rock Gs = 2.88 (granite), D_{50} = 1m





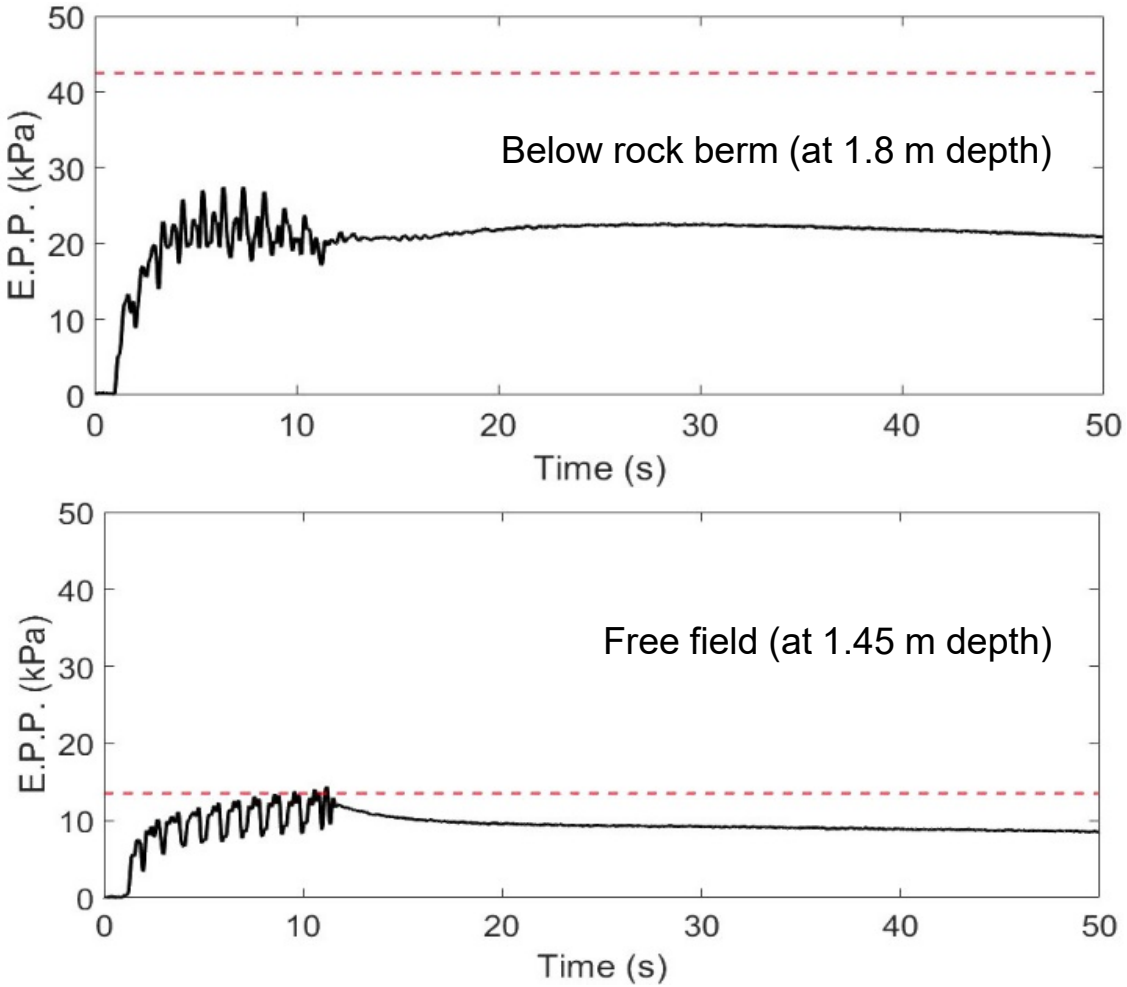
Results: rock settlement

- Comparison of sand side and rock side settlement.
- Sine wave with PGA = 0.17*g*
- Rock settlement >0.3m
- Characteristic stop start motion.
- Initial settlement delay due to a few cycles being needed to build excess pore pressure to induce liquefaction.

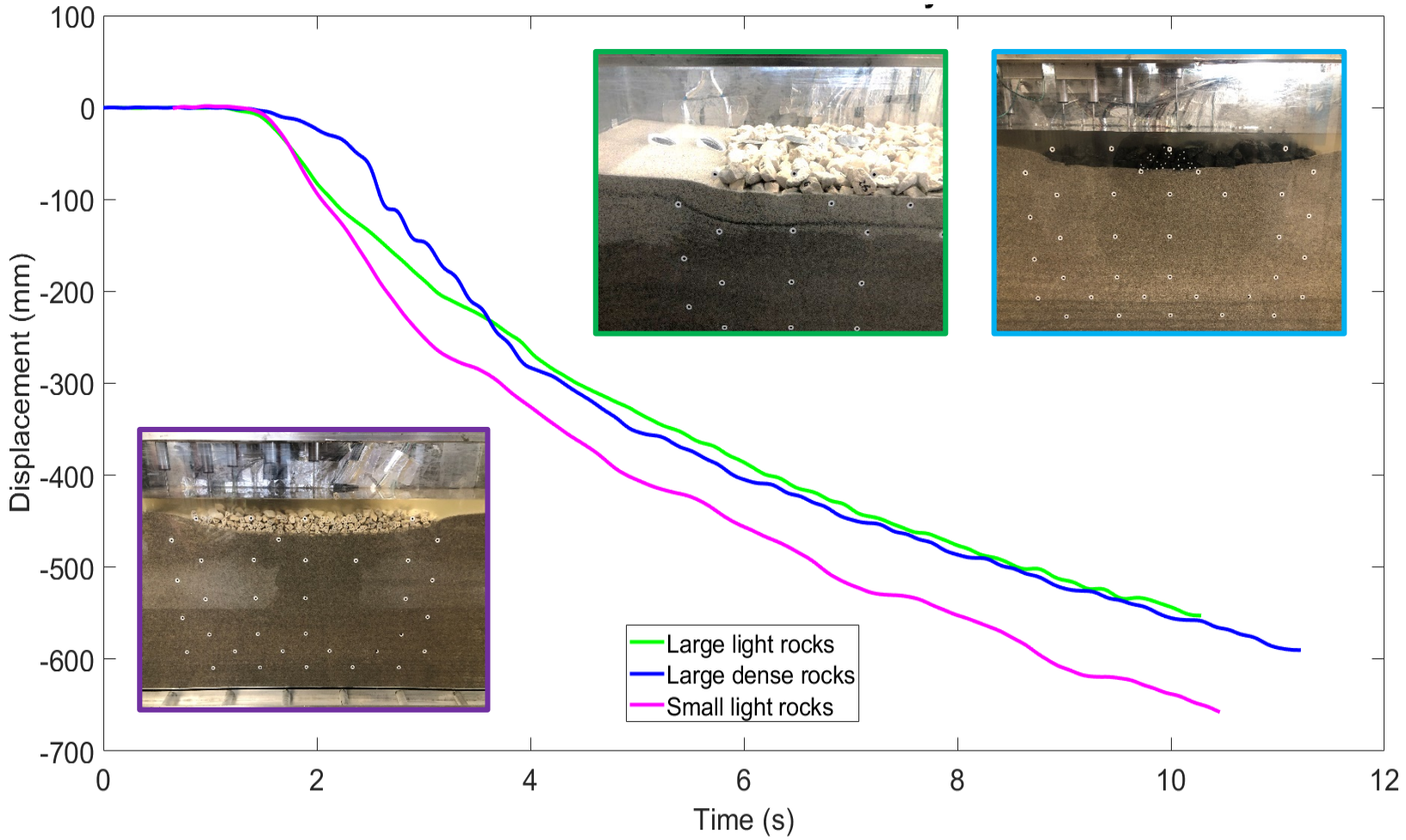


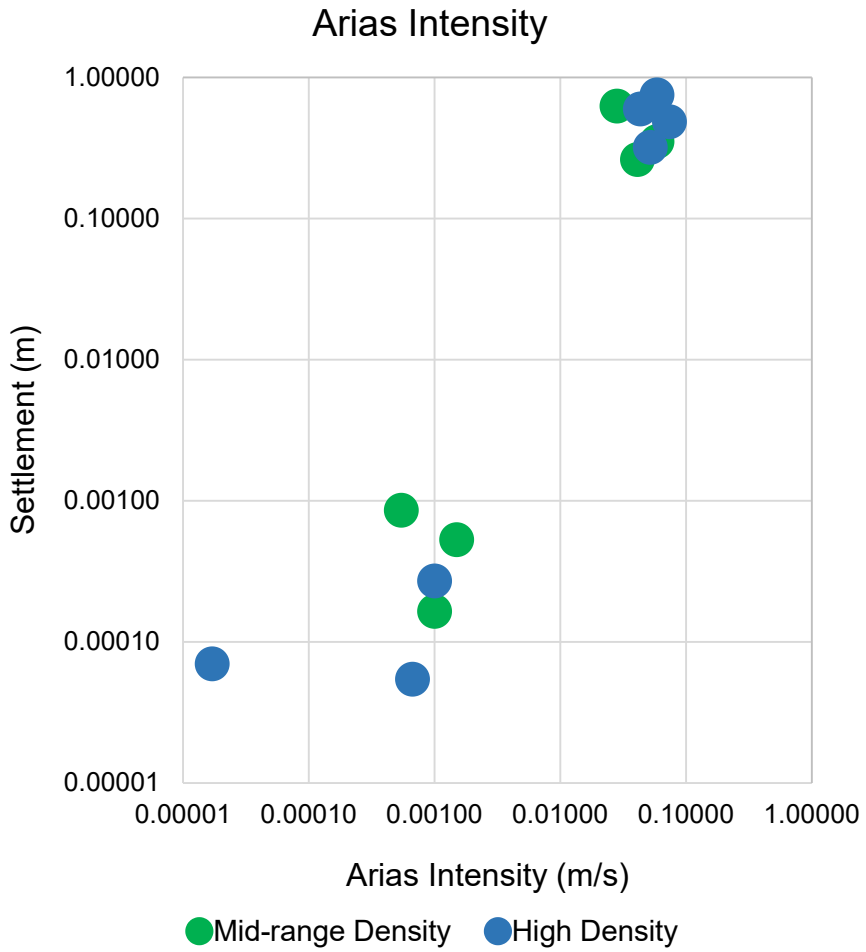
Results: comparison of excess pore pressures

- Increase in overburden pressure on rock side “out paces” the increase in excess pore pressure compared to the sand side and thus delays full liquefaction.
- Slower excess pore pressure build up on rock side, as rocks sink, the soil shears and dilates, this prevents pore pressures increasing.
- Liquefaction limit in dotted red line.
- Full liquefaction where r_u = 1.
- Still, significant rock settlement occurred.



Results: comparison of rock settlements





Conclusions

1. Rock berm settlements in the region of 300 mm are observed post seismic liquefaction.
2. The presence of rock delays the onset of full liquefaction compared to the free-field sand. (as theorised by Escribano (2017))
3. Despite not reaching full liquefaction, large settlements still occurred.
4. Small rocks settle more than larger rocks, as do higher density rocks (for large input motions).
5. The PIV technology deployed captures the sand failure mechanism during a dynamic centrifuge test.

Future work

- Explore the settlement of a plate
- Explore the effect of
  - Rock grading
  - Berm geometry
  - Further decrease rock size
- Inclusion of a model pile
  - Pre and post EQ push over test
- Further understand the evolution of excess pore pressure around a single rock

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Thank you

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